Dietary Overlap Between Introduced Fishes and Juvenile Salmonids In Lower Granite Reservoir, Idaho-Washington

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Abstract- *Dietary analysis was conducted on five introduced and two juvenile salmonid species collected in Lower Granite Reservoir during spring 1995 to quantify dietary overlap occurring during smolt rearing and out migration. We found that the diets of both introduced fishes and juvenile salmonids sampled were diverse, presumably as a result of unusually high spring flows that increased prey diversity in the reservoir. Results from this study suggest that similar food items of juvenile chinook salmon (Oncorhynchus tshawytscha) and steelhead (O. mykiss) are being found in introduced fishes, particularly chironomid larvae and pupae, and Ephemeroptera nymphs. Our Schoener Index analysis comparing the dietary biomass for all fishes considered in this study reflected these similarities, as values near or exceeding the critical level of overlap (>0.60) were found. However, based on the unlimited food resources and the relatively low abundance of selected introduced fishes in the reservoir, the biological significance of this dietary overlap for juveniles salmonids is likely not contributing to higher mortality in juvenile salmonids.*

Introduction

The Snake River watershed historically supported large runs of anadromous salmon *Oncorhynchus spp.* and steelhead *O. mykiss*. Currently, stocks of Snake River salmon have been listed as endangered under the Endangered Species Act (Menke 1993). The depressed status of these stocks has lead to a large number of scientific studies to identify key factors that have contributed to their decline. Although overfishing has substantially depleted some salmonid stocks, direct and indirect losses due to environmental modifications have had the greatest permanent effect on their viability (Williams 1989). Tributary dams, unscreeened irrigation diversions, habitat degradation and in-stream siltation from logging, mining, and grazing activities have eliminated or severely degraded many of the valuable spawning and rearing areas used by these fishes. Despite the severity of these deleterious effects on salmonid habitat, construction and operation of instream hydroelectric dams along the Columbia and Snake River systems may be the largest contributors to the declining salmon and steelhead runs in the inland northwest (Raymond 1988).

Extensive research has been conducted on effects of hydroelectric dams and resulting reservoirs on juvenile salmonid survival (Holmes 1958; Raymond 1969, 1979, 1988; Bell and Delacy 1972; Bell 1981; Curet 1994). Research has been directed primarily towards smolt mortality as a result of passage through turbine in-take and prolonged exposure to lethal concentrations of nitrogen gas (Raymond 1979, 1988). Recovery efforts have been made to alleviate the severity of these factors by developing transportation, collection, and by-pass facilities for juvenile salmonids, and modifying spillways to reduce gas supersaturation (Williams 1989). Raymond (1968) found that juvenile chinook salmon *O. tshawytscha* moved only one-third as fast through reservoirs as through free-flowing stretches of river. Prolonged migration time of smolts through the reservoir increases the probability of predation (Raymond 1979; Curet 1994), and may disrupt timing for optimal entry into seawater (Mahanken et al. 1982). However, understanding the deleterious effects of hydroelectric dams on juvenile salmonids is not complete and other contributing factors may exist.

Dietary overlap has been speculated as being a factor contributing to juvenile salmonid mortality in Lower Granite Reservoir (Poe 1992). Curet (1994) found that sub-yearling chinook salmon were feeding at about 27% of maximum during their brief rearing and migratory period in Lower Granite Reservoir. These results were consistent with other research conducted by Poe (1992) and Muir (1996) who found that smolts collected at Lower Granite Reservoir had high percentages of empty stomachs in contrast to migrants collected at other dams. Reduced consumption by juvenile salmonids in the Lower

Snake River reservoirs could be the result of changes in the benthic community that occurred as a result of the impoundment, specifically a decrease in diversity, availability, and abundance (Bennett and Shrier 1986). These changes in the prey base, combined with an established population of introduced fishes have elevated the concern of smolt mortality as a result of competitive interactions. In a preliminary study that investigated the possibility of dietary overlap in Lower Granite Reservoir, Bennett et al. (1997a) found that diets of several species of introduced fishes were similar to those of chinook salmon and steelhead in 1994 and 1995, suggesting that similar food items were being proportionally consumed by both introduced fishes and juvenile anadromous fishes in Lower Granite Reservoir. These results suggest the need for a more thorough evaluation of food habits between introduced fishes and anadromous salmonids in the lower Snake River reservoirs.

Dietary overlap among introduced fishes and juvenile salmonids needs to be determined to provide managers with adequate information for making decisions regarding the potential for restoration of Snake River salmonids. As a result, we evaluated the food items of juvenile salmonids and introduced fishes collected in Lower Granite Reservoir to assess the degree of dietary overlap.

Study Area

Lower Granite Dam, completed in 1975, impounds 53 km of the Snake River extending from the dam at Rkm 173.1 (Rm 107.5) in Washington into the Snake and Clearwater rivers in Idaho (Figure 1). The total surface area of the reservoir is 3,602 ha, with a mean depth of 16.6 m and maximum of 42.1 m (Curet 1994). Electrical power generation, navigation and recreational activities are the major uses of the dam and resulting reservoir (Bennett and Shrier 1986). The annual temperature ranges from 2 to 23 ^{o}C with no thermal stratification. Riparian vegetation along the shoreline is sparse as a result of the 1.52 m water level fluctuation from reservoir operations (Curet 1994). Lower Granite Reservoir is the uppermost impoundment on the lower Snake River that is encountered first by outmigrating Snake and Clearwater River chinook salmon and steelhead juveniles.

Lower Granite Reservoir was divided into three strata (stratum 1 Rkm 211 – 225.1 (Rm 131.0 - 139.75); stratum 2 Rkm 193.2 - 211 (Rm 120.0 - 131.0); and stratum 3 Rkm 173.1 - 193.2 (Rm 1075.5 - 120.0)) for sampling juvenile salmonids and introduced fishes (Figure 1). The shoreline was separated into 0.4-km sections of similar habitat types and each section represented one sample site, thus yielding 258 possible sites. The number of sites sampled within each stratum and habitat type was determined by the proportional allocation formula (Scheaffer et al. 1990). In 1995, 60 sites were randomly sampled semimonthly from May through July and monthly in April and August through November.

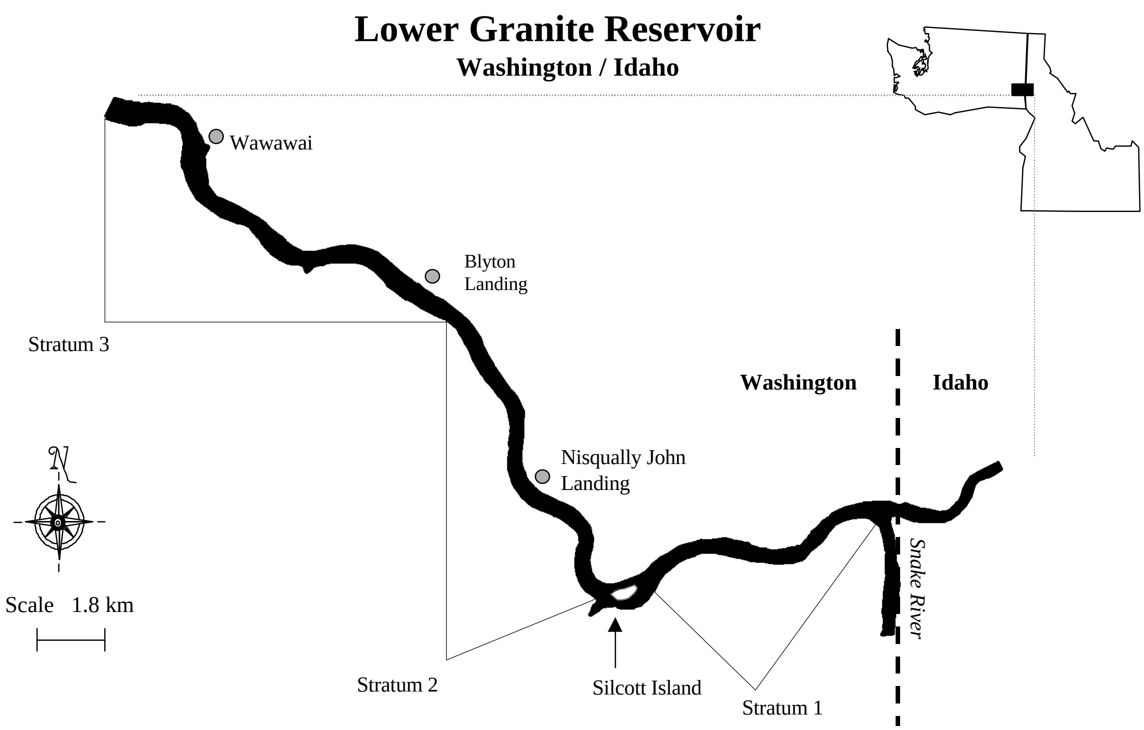

Figure 1. Map of Lower Granite Reservoir, Washington / Idaho.

Methods

Collection Procedures

Electrofishing and beach seining were used for shoreline collections of introduced and salmonid fishes. Electrofishing was conducted using a Smith-Root electroshocking boat for daytime and nighttime collections. The boat was operated parallel to the shoreline with current turned on and off through the length (0.4 km) of the site. A constant electrical output of 400 volts at 3 to 5 amps was used to stun fish without causing mortality. Beach seining was conducted using a 30.5-m x 2.4-m beach seine with a 2.4-m x 2.4-m x 2.4-m bag constructed of 0.6-cm knotless nylon mesh. The seine was placed parallel with, and approximately 5-25 m from the shoreline. The seine was pulled toward the shore, sampling an area from 366 m^2 to 1,830 m^2, respectively. Beach seining was conducted over cobble, talus, and sand/silt habitats. One to three hauls were conducted at each location depending on shoreline habitat.

All fishes sampled were placed in live wells immediately upon capture. Each fish was weighed (g) and measured for length (mm). Introduced fishes were measured to total length and juvenile salmonids were measured to fork length. Stomach contents were evacuated from fish anaesthetized with MS 222 using a modified lavage technique (Seaberg 1957), flushed into a mesh filter, and transferred to a sample container where they were preserved in 10% formalin. Fish were allowed to fully recover prior to release. A maximum of 5 to 10 stomachs of juvenile salmonids was sampled per location within each of the three strata. Juvenile salmonids longer than 100 mm were sampled for stomach contents, while yellow perch *Perca flavescens*, crappie *Pomoxis spp.* and sunfish *Lepomis spp.* longer than 70 mm were sampled for stomach contents.

Lab Analysis

Stomach contents of introduced fishes and juvenile salmonids were identified to the lowest practical taxonomic level in the laboratory using dissecting microscopes. Prey items were identified using several taxonomic keys: Borror et al. (1981), Merrit & Cummins (1984), Pennak (1989) and Wiggins (1996). Prey items were separated into taxonomic groups and enumerated. When possible, parts of insects were combined with similar prey items and the total number for each group was estimated. Digested weights were obtained by blotting prey items dry and weighing to the nearest 0.001 milligram. When prey items were not intact, head capsules were counted, and body parts were combined for weighing. Partially digested, unidentifiable foods were weighed as a group.

When fish were found in a stomach sample, fork length (nearest mm) was measured and weights were obtained to the nearest 0.001 milligram. When prey fish were too digested to be properly identify, diagnostic bones from cleitherum, opercle, dentary, hypural bones, and vertebrae were used to distinguish between salmonid and non-salmonid prey (Hansel et al. 1988). Species identification was further determined using a bone manual to aid in specific bone morphological traits.

Data Analysis

Stomach contents were analyzed for dietary overlap from five introduced fishes and two juvenile salmonids captured during April – June (spring) 1995. Stomach contents of fishes collected in strata 1-3 were pooled, and analyzed on a reservoir wide basis. Dietary analysis of introduced fishes and juvenile salmonids was divided according to fish species.

Differences in the diets of juvenile salmonids and introduced fishes were determined using the average of the weight percentage of each prey item consumed. Prey items were consolidated into 28 categories based on taxonomic distinction. Total biomass (g) of all food categories in each fish species was then calculated. The percent of each prey category based on total biomass was averaged to derive the percent composition by weight of each prey category for each fish species.

Comparisons of each prey category consumed were made between introduced fishes and juvenile salmonids based on the mean percent biomass (g). A measure of biomass is the most appropriate when calculating dietary overlap (Wallace 1981). Percent biomass of dietary items was based on identifiable prey items, non-food items and unidentified prey were omitted in the comparison. To test for dietary overlap between introduced fishes and juvenile salmonids, we employed the Schoener Index (Wallace 1981). Values for the Schoener Index vary from 0 when the samples are completely distinct (containing no food categories in common) to 1 when the samples are identical with respect to proportional food category composition. Dietary overlap is considered to be biologically significant when the value exceeds 0.6 (Zaret and Rand 1971). The Schoener Index is calculated as:

$$\alpha = 1 - 0.5 \left(\sum_{i=1}^{n} \left| p_{xi} - p_{yi} \right| \right)$$

where, p_{xi} and p_{yi} are the proportions of food resources (i) used by species x and y, and n is the total number of resource categories used by each species. The Schoener Index values for each comparison were used to determine which species exhibited dietary overlap.

Results

Ninety-two different prey items were identified from the stomachs of 302 introduced fishes and 583 juvenile salmonids sampled during spring 1995 in Lower Granite Reservoir. Lengths of introduced fishes and juvenile salmonids were similar (Table 1.). The biomass of prey items consumed by juvenile salmonids was about three times lower than in introduced fishes, except for white crappie that were similar.

Dipteran larvae and pupae (mainly chironomidae) accounted for the highest mean biomass of identifiable prey items found in all fishes, except in juvenile chinook salmon where Ephemeroptera nymphs comprised the highest percentage (27.0%; Table 2.). Ephemeroptera nymphs contributed the second highest mean dietary biomass in the stomachs of pumpkinseed (21.5%), white crappie (24.1%), black crappie (21.4%), and yellow perch (21.9%). Combined, these prey items accounted for greater than 50% of the mean biomass in the diets of pumkinseed (58.4%), white crappie (66.5%), black crappie (53.2%), yellow perch (53.3%) and juvenile chinook salmon (51.7%). Terrestrial based insects, predominately Coleoptera, Hymenoptera, and adult Diptera, accounted for a higher percent of the mean biomass in bluegill (25.2%) and juvenile chinook salmon (31.3%) and steelhead (32.5%) than in other fishes. Evidence of piscivory existed predominately in the diets of white and black crappie (20.3% / 23.7% mean biomass, respectively), and yellow perch (25.1% mean biomass). Fish in the diets of these species consisted primarily of larval fishes. Fish accounted for a small proportion of the dietary mean biomass found in pumkinseed (4.2%), juvenile chinnok salmon (0.8%) and steelhead (0.3%). Crustaceans were found in the diets of all fishes sampled, and consisted primarily Amphipoda. Zooplankton comprised greater than 10% of the mean biomass in the diets of bluegill (16.7%) and juvenile steelhead (11.4%).

Schoener Index values were high between all introduced fishes and juvenile salmonids, however a value of significant dietary overlap (0.60) was exceeded only between bluegill and juvenile chinook salmon (0.61) and steelhead (0.69) (Table 3.). Schoener index values comparing pumkinseed, white and black crappie, and yellow perch with juvenile chinook salmon were higher than 0.57, whereas values comparing these introduced fishes with juvenile steelhead were comparably lower.

Table 1. Total length, total weight of all food items, and weight of food items per fish for the five introduced and two anadromous fishes used in the diet overlap analysis. Values indicate the mean and standard error. Ranges are presented in paraentheses.

Fish Species	Total number of fish	Total Length (mm)	Total biomass (g) food items	Biomass food items/fish
Pumpkinseed	67	140.4+/-2.5 (80 - 181)	22.46	0.34+/-0.07 (0.00-3.00)
Bluegill	16	151.4+/-5.6 (111 - 188)	4.61	0.29+/-0.08 (0.01-1.20)
White crappie	106	120.8+/-4.3 (65 - 239)	15.74	0.15+/-0.05 (0.00-4.97)
Black crappie	79	165.6+/-6.0 (55 - 296)	36.56	0.46+/-0.12 (0.00-7.14)
Yellow perch	37	194.1+/-7.6 (96 - 282)	8.34	0.23+\-0.05 (0.00-1.42)
Chinook salmon	379	122.5+/-1.0 (81 - 229)	32.2	0.08+/-0.01 (0.00-0.71)
Steelhead	204	172.9+/-3.3 (86 - 295)	27.27	0.13+/-0.02 (0.00-2.19)

Table 2. Percent of identifiable prey catagories found in the stomachs of five introduced fishes and two juvenile salmonids from Lower Granite Reservoir, Washington/Idaho. "T" indicates items in diet were terresterial invertebrates, "A" indicates aquatic invertebrates, "C" indicates crustacean, "F" indicates fish, and "O" indicates other.

Prey Category	Pumpkinseed (N = 65)	Bluegill (N = 16)	White crappie (N = 106)	Black crappie (N = 79)	Yellow perch (N = 36)	Chinook salmon (N = 379)	Steelhead (N = 204)
O Plant	0.02	0.7			4.8	0.4	0.02
A Misc. aquatic insects	3.9	9.19	2.1	3	0.6	0.9	1.8
T Misc. terrestrial insects	0.02	1.3			0.01	1	2.7
O Annellida	16.2	10		0.15	0.1	0.2	2.7
C Amphipoda	7.3	12.7	5.1	7.9		2.7	7.9
C Cladocera	0.02		1.9	0.3	0.01	0.01	0.02
C Copopoda	0.4	3.8	0.6	1.6	3.4	0.3	0.3
C Decapoda	1.3	0.01	0.1			0.01	
C Isopoda	0.5	0.1	0.02	0.02		0.01	3
C Ostracoda	0.02	0.2	0.02	0.01		0.01	0.3
T Ephemeroptera (adults)			0.2			0.8	1.8
A Ephemeroptera (nymphs)	21.5	9	24.1	21.4	21.9	27	10.2
T Plecoptera (adults)		2.2	0.2	1.4	2.6	0.6	0.4
A Plecoptera (nymphs)			0.03	2.4		0.6	2.2
T Hemioptera		0.6		0.01		1	1.4
T Trichoptera (adults)	0.8	0.3	0.03	0.9		2.6	1.3
A Trichoptera (larvae)	1.9	3.7	1.3	2.3	1.4	3.4	1.8
T Coleoptera	1.5	6.1				1.6	7
A Diptera (larvae/pupae)	36.9	24.9	42.4	31.8	31.4	24.7	23.7
T Diptera (adults)	1.2	5.8	0.3	1.5	1.1	11.8	9.1
O Mollsca	1.1			0.01			0.9
T Homoptera	0.2	0.3		0.3	0.9	2.7	2.5
T Hymenoptera	0.1	8.6		0.6	0.01	9.1	6.4
O Insect exuviae	1	0.5	1.3	0.7	6.6	7.8	12.3
F Fish UID / larval	4.1		8.9	18.1	15.8	0.4	0.3
F Salmonid fishes			2.7	4	5		
F Non-salmonid fishes	0.02		8.7	1.6	4.4	0.4	
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**

Table 3. Schoener Index values comparing diet-overlap between introduced fishes and juvenile salmonids collected in Lower Granite Reservoir during spring (April-June) 1995. Asterisks (* *) indicate significant dietary overlap.

Spring (April-June) 1995	Chinook salmon (N=397)	Steelhead trout (N=204)
Pumpkinseed (N=65)	0.57	0.54
Bluegill (N=16)	*0.61*	*0.69*
White crappie (N=106)	0.57	0.45
Black crappie (N=79)	0.58	0.53
Yellow perch (N=36)	0.59	0.46

Discussion

Our results support speculations of other researchers (Poe 1992; Muir 1996) that dietary overlap is occurring during downstream migration of juvenile salmonids in Lower Granite Reservoir. Diptera (Chironomid) larvae and pupae, and Ephemeropteran nymphs were found consistently in diets of all fishes sampled, and appeared to be the most selected prey item in spring 1995. Our Schoener analysis reflected these consistencies, as values near to or exceeding the critical level of overlap (0.60) were found. However, the effects of this diet overlap may not be highly significant to the survival of juvenile chinook salmon and steelhead in Lower Granite Reservoir.

During periods of smolt rearing and out migration, food resources in Lower Granite Reservoir are likely not limiting. Lower Granite is unique among the four Lower Snake River reservoirs as free flowing tributaries (Clearwater and upper Snake Rivers) feed its headwaters. Davis (preliminary data, University of Idaho) in his evaluation of invertebrate drift in Lower Granite Reservoir found that during spring high flows, drift from these riverine tributaries increased aquatic insect diversity and abundance in the reservoir. This source of invertebrate recruitment likely increases the prey base in the reservoir during smolt migration. Concern for dietary competition may be warranted during periods or years of low flow when invertebrate recruitment is minimal; as was indicated by Davis' (unpublished data, University of Idaho) results. Under this condition, dietary overlap may become more critical if the aquatic invertebrate community in the reservoir were unable to support the food demands of juvenile salmonids. Measurements of benthic invertebrate standing crop recorded during periods of smolt migration indicated no correlation between fluctuations in benthic invertebrate densities and peak juvenile salmonid abundance in the reservoir (Bennett et al. 1997b). Together, these factors suggest that food resources are unlimited in Lower Granite Reservoir during juvenile salmonid migration. Thus, the effects of dietary overlap on the survival of juvenile salmonids are likely minimal.

Effects of food resource competition may be further minimized for juvenile salmonids as a result of the relatively low abundance of the five introduced fishes we examined in Lower Granite Reservoir. Bennett et al. (1997c) examined persistence and stability of the resident fish assemblage in Lower Granite using fish abundance data collected during 1985 through 1993. Although results from this 8-year study indicated a reservoir wide increase in Centrarchid fishes numerically, by 1993 abundances of bluegill, pumkinseed, black and white crappie, and yellow perch accounted for less than 7% of the resident fish assemblage. If under the worse-case scenario food resources were to become limiting in the reservoir, based on these relatively low abundance estimates, it is unlikely dietary overlap among these fishes would seriously affect juvenile salmonid survival.

The importance of Diptera (Chironomid) larvae and pupae, and Ephemeroptera nymphs in the diets of all fishes sampled may partially be explained by the availability concept in fish feeding dynamics, in which seasonal diet changes are related to seasonal changes in abundance and availability of various food items (Dauble et al. 1980; Becker 1970; Carlander 1969). Several studies (Dorband 1980; Bennett and Shrier 1986; Bennett et al. 1990; Bennett et al. 1993; Bennett et al. 1997b; Davis, unpublished data, University of Idaho) have reported that Dipteran (most prominently Chirnomid) and Ephemeropteran species are dominant components of the reservoir's aquatic invertebrate fauna in spring. Presence of these prey items in the diets is likely related to their high abundance.

Although we found the diet contents of selected introduced fishes with respect to aquatic based insects were similar to those of juvenile salmonids, we did observe differences in the consumption of terrestrial based insects (mainly adult Dipterans, Coleopterans and Hymenopterans) and fish. This degree of variability slightly decreased dietary overlap for juvenile salmonids, particularly with white and black crappie and yellow perch. It is possible during migration through the reservoir, juvenile salmonids are more surface oriented in response to increased buoyancy from smoltification (Pinder and Eales 1969). This behavior possibly promoted the increase in feeding of juvenile salmonids on prey items floating at or near the water surface, which may account for the relatively high biomass of terrestrial based insects in their diet. In contrast, selected introduced fishes probably fed more frequently along littoral areas of the reservoir where Bennett and Shrier (1986) found the abundance of small fish were highest.

In this study, we sought to determine the degree of dietary overlap among two juvenile salmonid and five introduced fishes in Lower Granite Reservoir. While our analysis was limited to data collected during a single sampling period (April-June, 1995), our results suggest that, at least during some portions of their migration through the reservoir, juvenile salmonids are consuming similar prey items as selected introduced fishes, and thus dietary overlap occurs. However, other biological factors that exist in the reservoir related to invertebrate availability and relative fish abundance, no doubt lessen the effects of dietary overlap for juvenile salmonids.

Care must be taken when evaluating our results of dietary overlap among selected introduced fishes and juvenile salmonids. Our analysis was intended to assess dietary overlap that exists on a reservoir wide basis. Therefore, spatial comparisons between upper, middle and lower reservoir areas were not thoroughly evaluated and should be examined, as prey abundance throughout the reservoir is probably not uniform. Our results, while accurately portraying dietary overlap for yearling chinook salmon, did not evaluate it among sub-yearling chinook salmon. Because of their extended rearing period in the reservoir, diet overlap with introduced fishes may be more extensive with subyearling chinook salmon and should be further examined.

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